DEVELOPMENT OF A NATIONAL NITROGEN OXIDES (NO_x) AND VOLATILE ORGANIC COMPOUNDS (VOC) MANAGEMENT PLAN FOR CANADA

FIRST REPORT TO CANADIAN COUNCIL OF MINISTERS OF THE ENVIRONMENT (CCME)
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EXECUTIVE SUMMARY

Federal / Provincial Long Range Transport of Air Pollutants Steering Committee

Comité directeur fédéral / provincial sur le transport à distance des polluants atmosphériques

Province of British Columbia
Ministry of Environment and Parks

Gouvernement du Québec
Ministère de l'Environnement

Alberta
ENVIRONMENT

New Brunswick
Department of Municipal Affairs and Environment

Saskatchewan
Environment and Public Safety

Community & Cultural Affairs

Manitoba
Environment and Workplace Safety and Health

Nova Scotia
Department of the Environment

Environment Ontario

Province of Newfoundland
Department of the Environment

Canada

FURTHER MANAGEMENT OF EMISSIONS OF NITROGEN OXIDES AND VOLATILE ORGANIC COMPOUNDS IN CANADA

Summary Report

Federal/Provincial LRTAP
Steering Committee

March 1989

Updated July 1989
(See Appendix A)

SUMMARY HIGHLIGHTS

Nature of the Problems

- About one half of the Canadian population is exposed to ground level ozone concentrations which are known to have health effects. Ozone levels in many agricultural areas in Canada exceed the recommended level to protect crops during the growing season.

- Ground-level ozone is the key NO_x and VOC-related ambient air quality problem in Canada; actions necessary to achieve environmental quality requirements for ozone will result in all other NO_x and VOC-related domestic environmental quality requirements being met with the exception of those that may be established for specific toxic VOCs.

- In the absence of further emission management actions, Canadian emissions of NO_x and VOCs are currently forecast to increase by 24 percent and 7 percent respectively between 1995 and 2005.

- The scientific understanding of the nature, causes and solutions of NO_x and VOC-related environmental quality problems is adequate to proceed with further emission management actions and to know that these actions will produce the intended results.

- Achieving domestic environmental quality requirements for ozone necessitates further management of NO_x and VOC emissions on a regional basis in Canada and reductions in the transboundary flows of these pollutants from the United States.

- Existing and emerging international environmental obligations indicate that, as a minimum, total national emissions and/or the transboundary flows of NO_x and VOCs must not increase above existing levels.

- Thus, in addition to the actions required to achieve domestic environmental quality requirements, agreements and measures must be put in place to manage total national emissions and transboundary flows of NO_x and VOCs.

- The principal sources of current and future NO_x emissions in Canada are motor vehicles, off-road diesels, natural gas production and power plants; the principal sources of current and future VOC emissions in Canada are gasoline-powered motor vehicles, the gasoline fuel cycle from production to vehicle refuelling, refineries and petrochemical plants, application of surface coatings and solvent use.

Nature and Scope of Possible Canadian Actions

- A menu of technologies and other measures are available to further manage current and future emissions of NO_x and VOCs in Canada.

- Canadian actions to further manage NO_x and VOC emissions from stationary sources should focus on:

  - reductions at existing power plants, with the degree of reduction being a function of such factors as the use and the life expectancy of the unit;

  - application of stringent emission limits on new sources based on best available technology that is economically achievable;

  - emission reductions at refineries and petrochemical plants through the use of best available technology that is economically achievable;

  - emission reductions from the application of surface coatings and use of solvents through the use of best available technology that is economically achievable and/or product substitution or reformulation;

  - implementation of energy productivity improvements; and,

  - development and use of intrinsically clean industrial process technologies and energy production technologies.

- Canadian actions to further manage NO_x and VOC emissions from mobile sources should focus:

  - emission reductions in the gasoline fuel cycle from production to vehicle refueling through the use of best available technology that is economically achievable, reducing fuel volatility and altering fuels and fuel composition;

  - tightening new vehicle emission standards (tailpipe and evaporative losses) to state-of-the-art levels;

  - implementation of inspection and maintenance programs for in-use vehicles to ensure technology performance;

- implementing emission standards for new on-road and off-road diesel engines based on state-of-the-art design and operation; and,

- development and use of intrinsically clean modes of transportation.

- The plan of action to further manage NO_x and VOC emissions in Canada should utilize both regulations and market-force driven initiatives.

- Any Canadian actions to further manage NO_x and VOC emissions should take into account their impact on other related problems such as acid rain, global warming, stratospheric ozone depletion and toxic air pollutants and the actions that are being taken, developed or contemplated to deal with these problems.

Jurisdictional Authorities and Responsibilities

- The plan of action for further management of NO_x and VOC emissions in Canada should comprise both uniform national actions and regionally tailored actions implemented through the complementary use of federal and provincial authorities.

Timeframe

- The specific plan of action for further management of NO_x and VOC emissions in Canada should be a phased program with all necessary measures in place by 1999.

Consultation Plan

- A workshop process should be used to consult with all stakeholders on the definition of the problems, the nature and scope of possible actions and the issues surrounding the problems and the actions.

TABLE OF CONTENTS

INTRODUCTION	1
NATURE OF THE PROBLEMS	6
NATURE AND SCOPE OF POSSIBLE CANADIAN ACTIONS	26
JURISDICTIONAL AUTHORITIES AND RESPONSIBILITIES	34
TIMEFRAME	36
ISSUES	37
CONSULTATION PLAN	45

1. INTRODUCTION

a) Purpose of Report

- In October 1988, federal and provincial environment ministers instructed that a comprehensive plan to further manage nitrogen oxides (NO_x) and volatile organic compounds (VOC) emissions in Canada be developed.

- This summary and the supporting annexes provide the basis for the first phase of consultations with stakeholders on: the nature of NO_x and VOC related problems in Canada and international obligations pertaining to these pollutants; the nature and scope of further emission management actions that could be considered in Canada; and, the issues surrounding the definition of the problems and the implementation of possible actions.

- The results of the first phase of consultations will be reported to the Canadian Council of Resource and Environment Ministers (CCREM) in October; the second phase of consultations on the detailed plan of action will begin shortly thereafter.

b) Background

- There are three requirements influencing the further management of NO_x and VOC emissions in Canada:

  - Canadian domestic air quality problems;

  - possible inclusion of measures to deal with the transboundary NO_x/VOC/ozone issue in a Canada/U.S. air quality agreement dealing with acid rain controls; and

  - the obligations contained in the United Nations Economic Commission for Europe (ECE) NO_x emission control protocol.

i) Ground-level ozone is the principal NO_x and VOC related-air quality problem in many areas in Canada.

- About one half of the Canadian population is exposed to ozone levels which are known to have health effects.

- The total commercial value of ozone sensitive crops grown in areas where ozone levels exceed the damage threshold is estimated at more than $2 billion; forest resources potentially at risk are estimated at several billion dollars.

- Reducing ozone concentrations to acceptable levels requires further emission management in Canada and reductions in transboundary flows from the United States.

ii) Canada/U.S.

- Compliance with local ambient air quality requirements for ozone is one of the most pressing issues in the United States; it is highly probable the U.S. Clean Air Act will be amended within the next year to deal with this issue.

- Since the issue is a transboundary one as well as a domestic one in both Canada and the United States, it is quite possible NO_x and VOC emission control targets and schedules will be considered for inclusion in a Canada/U.S. air quality agreement.

iii) ECE NO_x emission control protocol.

- The basic obligations in the protocol require Canada to freeze NO_x emissions or transboundary flows at their 1987 level by 1994 (which existing abatement actions will already do) and implement further actions (which must be negotiated with the United States) to control them to the level required to achieve internationally agreed environmental quality targets.

- A working group has been established under the ECE to develop recommendations for a VOC emission control protocol; the protocol will likely address the roles of VOCs in both ozone formation and as toxic air pollutants.

- Recognizing the foregoing, federal and provincial environment ministers made the following decisions at their October 1988 meeting:

  i) The Federal/Provincial LRTAP Steering Committee was instructed to develop a comprehensive plan to further manage NO_x and VOC emissions in Canada.

  ii) The plan should be designed to achieve Canada's own domestic environmental protection requirements as well as to meet international obligations.

  iii) The Federal/Provincial LRTAP Steering Committee should consult with all interested stakeholders in the development of the plan.

iv) The Federal/Provincial LRTAP Steering Committee should ensure that the Federal/Provincial Research and Monitoring Coordinating Committee develops a plan of action to verify the effectiveness of further Canadian NO_x and VOC emission management measures.

v) Both plans of action are to be completed within two years.

vi) The LRTAP Steering Committee should report to CCREM every six months.

vii) The Ministers noted that further improvements in energy productivity and conservation should be a key feature in the plan of action.

viii) Ministers agreed that the issue of fuel volatility should be addressed in the development of the national plan of action.

c) Other Related Issues

- There are a number of other issues that must be taken into account in developing a plan of action to further manage Canadian NO_x and VOC emissions. These include: acid rain; greenhouse effect; stratospheric ozone depletion and toxic air pollutants.

i) Acid Rain

- With respect to the acid rain issue, the concern is the extent to which any further NO_x and VOC emission management initiatives assist or aggravate the actions being taken to meet the scheduled reductions in sulphur dioxide (SO_2) emissions. Since the Federal/Provincial LRTAP Steering Committee is charged with overseeing implementation of the Canadian acid rain control program and developing the plan of action for further management of NO_x and VOC emissions, any potential problems can be resolved in this forum.

ii) Greenhouse Effect and Stratospheric Ozone Depletion

- With respect to the greenhouse effect and stratospheric ozone depletion issues, the concern is the extent to which any further NO_x and VOC emission management initiatives are compatible with the nature and scope of actions being taken, or those that may be taken, to address these issues.

  - For instance, nitrous oxide (N_2O) is known to be a global atmospheric warming agent and a

stratospheric ozone depleting agent. About one-third of total global N_2O emissions are anthropogenic, resulting mainly from fertilizer application and to a lesser extent from large stationary combustion sources. Mobile sources are not significant emitters of N_2O.

- Nitrous oxide is estimated to contribute about 5% to global warming and will be of increasing concern from that perspective in the years ahead. It would normally also contribute to stratospheric ozone depletion. However, in the present situation of elevated levels of chlorine compounds in the stratosphere (mainly due to chlorofluorocarbons), a situation that will prevail for decades, ozone depletion is slowed by increasing N_2O concentrations due to interference of the N_2O with the chlorine-catalyzed destruction of ozone. However, with a residence time in the atmosphere of up to 150 years, once reductions in releases of chlorofluorocarbons and halons have reduced the levels of chlorine compounds in the stratosphere, N_2O will become a stratospheric ozone depletor.

- Coordination of initiatives to further manage NO_x and VOC emissions and their potential relationship with initiatives to deal with stratospheric ozone depletion will be done through the members of the Federal/Provincial LRTAP Steering Committee.

- The major contributor to the greenhouse effect is carbon dioxide (CO_2) emissions from combustion (stationary and mobile sources). While precise objectives are yet to be established, major reductions in CO_2 emissions are likely to be required in the foreseeable future. Thus, initiatives to further manage NO_x and VOC emissions should neither significantly aggravate the current CO_2 emission situation nor detract from the ability of emitters to deal with CO_2 emission management initiatives that will be required in the future.

- Linkages will have to be established between the Federal/Provincial LRTAP Steering Committee and institutional mechanisms (both existing and planned) dealing with the global warming issue.

iii) Toxic Air Pollutants

- A number of toxic air pollutants can be formed during the photochemical reactions leading to ozone

formation. In addition, many volatile organic emissions important in ozone formation are known or suspected carcinogens in their own right. Actions to deal with ground-level ozone problems will reduce the levels of toxic photochemical air pollutants as well as some of the toxic emissions.

- Controls on emissions of toxic air pollutants are dealt with through the Canadian Environmental Protection Act and similar provincial programs.

2. NATURE OF THE PROBLEMS

- National Ambient Air Quality Objectives are developed through the Federal/Provincial Advisory Committee on Air Quality (FPACAQ) which reports to the CCREM Committee of Deputy Ministers. The FPACAQ Air Quality Objectives Subcommittee, comprised of experts in the fields of human health effects, vegetation effects and pollution measurement and control, develop the objectives for approval by FPACAQ and CCREM Deputy Ministers. The objectives are then provided to Environment Canada and provincial governments in the form of recommendations.

- Ambient air quality requirements (e.g., standards, objectives, criteria, etc.) have been established in Canada at the federal and provincial levels to protect human health and the environment from damage due to nitrogen dioxide (NO_2) and ozone (O_3) air pollution. Substantial empirical evidence is available to provide guidance on a target for nitrogen compound deposition. A comparison of the federal maximum acceptable levels, with ECE critical levels and U.S. primary standards, is contained in Table 1.

- Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick and Newfoundland have ambient air quality standards at, or very similar to, the federal maximum acceptable levels. British Columbia and Nova Scotia use the federal objectives in their permitting processes.

TABLE 1 COMPARISON OF THE FEDERAL MAXIMUM ACCEPTABLE LEVELS WITH STANDARDS IN OTHER COUNTRIES
(All units in micrograms per cubic metre [ug/m^3] except where indicated)

Pollutant	Exposure	Federal	ECE	U.S.primary
NO_2	1hr	400	800	-
	24hrs	200	-	-
	Annual	100	30[1]	100
O_3	1hr	160	150	235
	8hrs	-	60	-
	24hrs	50	-	-
	Annual	30	-	-
	Growing Season	64[2]	50	-
Nitrogen Deposition	(kg/ha/yr)[3]			
Low Productivity Forests[4]		-	3-11	-
High Productivity Forest[4]		-	7-20	-

1. Assumes SO_2 conc. of 30 ug/m^3 and O_3 conc. of 60 ug/m^3.
2. Recommended maximum average concentration June to August (0900 to 1600 hours).
3. Kilograms per hectare per year.
4. In Canada, low productivity forests tend to be in northern regions and high productivity ones in more southern areas.

a) Environmental, Health and Economic Impacts in Canada

i) Ozone

- Ozone is produced in the lower atmosphere from photochemical reactions involving two precursor pollutants: volatile organic compounds (VOCs) and NO_x. Because the chemical reactions depend on both sunlight and temperature, ozone concentrations tend to be highest on hot, sunny days.

- "Background" ozone levels in many areas of Canada have increased to the point (40 to 50 ug/m^3) where they have become a factor in the frequency with which environmental quality targets for ozone are exceeded since ozone episodes are superimposed on "background" levels. This is particularly true for the growing season mean level. "Background" ozone levels are associated with stratospheric (upper atmosphere) ozone intrusion and regional scale emissions of precursor polluants. Reducing global/regional scale precursor emissions will reduce "background" levels of ozone.

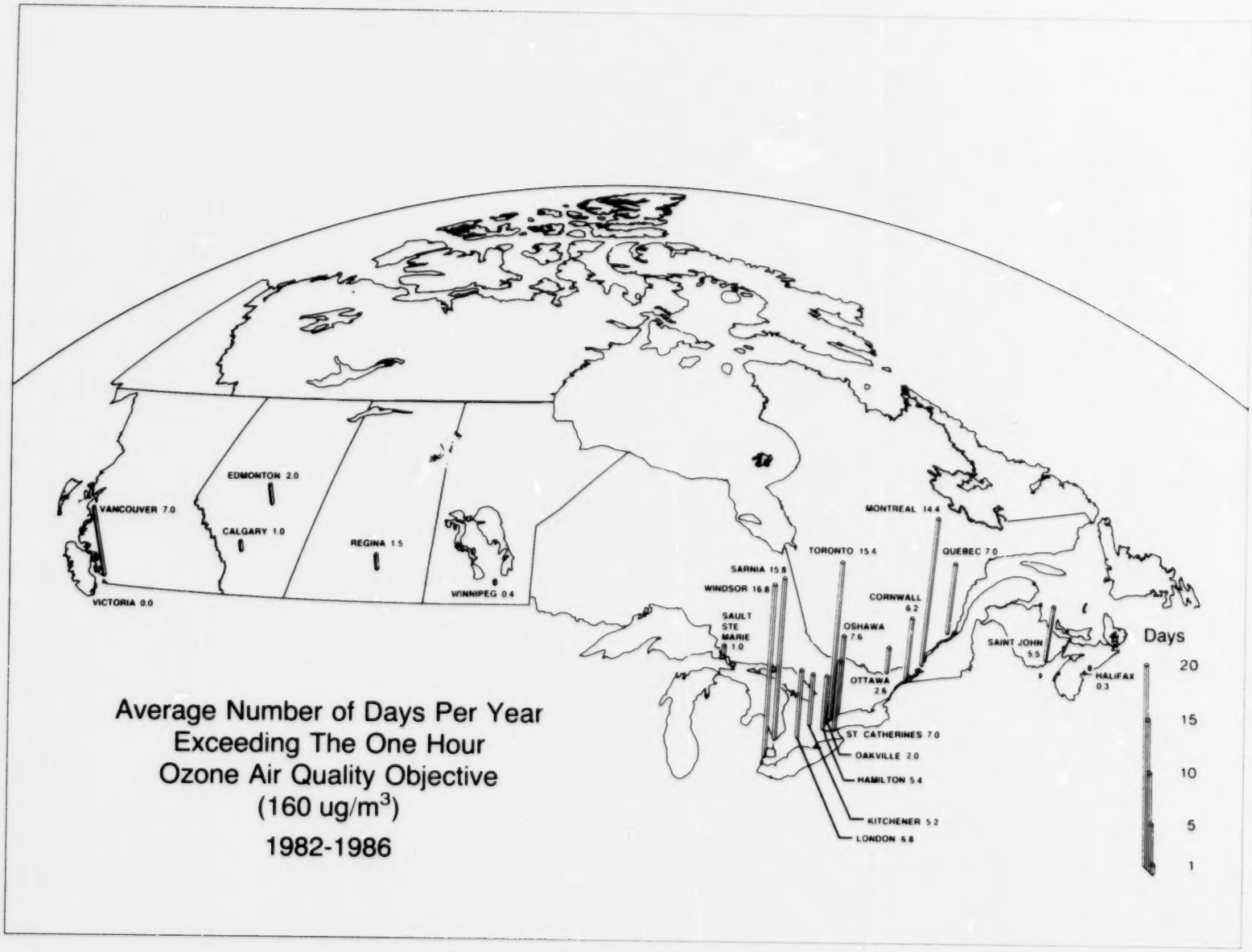
- During the summer months, about one half of the Canadian population is exposed to ozone levels which are known to have health effects. Peak concentrations can be more than twice the maximum acceptable level. Table 2 summarizes preliminary 1988 ozone data for a number of selected urban areas. Over the past five years, Victoria is the only major urban area (populations greater than 50,000 where routine monitoring takes place) in Canada that has not recorded readings in excess of the maximum acceptable level (see figure 1). The urban areas in the B.C. lower mainland and the Windsor-Quebec City corridor and Saint John, New Brunswick are the areas where ozone levels most frequently exceed environmental quality requirements.

TABLE 2 PRELIMINARY 1988 OZONE DATA FOR SELECTED URBAN AREAS

City	Maximum 1 hr. Level (ug/m^3)	Number of Hours Greater than 160 ug/m^3*	Number of Hours Greater than 300 ug/m^3
Vancouver**	205-415	9-32	0-4
Edmonton	160	0	0
Calgary	175	1	0
Regina	130	0	0
Winnipeg	180	1	0
Toronto**	310-360	92-138	0-3
Sudbury	220	78	0
Kitchener	230	137	0
Ottawa	250	55	0
Montreal**	255-350	23-153	0-17
Saint John***	195	31	0
Halifax	155	0	0

* Maximum acceptable level.
** Ranges refer to data from a number of sites within the metropolitan area.
*** Data for May and June only.

FIGURE 1.



Average Number of Days Per Year
Exceeding The One Hour
Ozone Air Quality Objective
(160 ug/m^3)
1982-1986

- There is also evidence of high ozone concentrations in many rural areas in Canada. Information from selected sites in the Maritime provinces, Quebec, Ontario, Alberta and British Columbia indicates concentrations above the recommended growing season mean concentration for ozone to protect agricultural crops as well as exceedances of human health-related requirements (see Table 3).

TABLE 3 OZONE CONCENTRATIONS AT SELECTED RURAL SITES (1987)

Location	Growing Season Avg. (ug/m^3)[1]	Maximum 1 hr Avg. (ug/m^3)[2]	Numbers of Hours Greater than 160 ug/m^3
Kejimkujic, N.S.	62	140	0
Pt. Lepreau, N.B.[3]	69	220	56
Blissville, N.B.[3]	59	192	22
St. Étienne, P.Q.	78	220	11
St.Barnabé, P.Q.	78	240	12
Simcoe, Ont.	98	234	72
Mandaumin, Ont.	96	268	133
Huron Park, Ont.	90	242	89
Crossfield, Alta.	74	160	1
Abbotsford, B.C.	66	234	15
Seymour Lake, B.C.	72	198	12
Kelowna, B.C.	75	135	0

1. Recommended maximum acceptable level is 64 ug/m^3
2. Maximum acceptable level is 160 ug/m^3
3. 1988 data

ii) Local NO_2 Air Quality

- NO_2 concentrations in Canadian cities are now generally below maximum acceptable levels. However, in 1987, sites in Montreal and St. Catharines exceeded the 24-hour maximum acceptable level (on 14 and 15 occasions respectively) and sites in Toronto, Sarnia, St. Catharines and Calgary exceeded the 1-hour maximum acceptable level one time each. Further improvements should occur until the mid 1990's as the full benefit of the 1987 and 1988 federal new motor vehicle emission standards take effect. In the late 1990s, increases in the number of vehicles and vehicle miles travelled will more than off-set the benefits of these standards. Over the past five years, cities in British Columbia, Alberta, Saskatchewan, Ontario and Quebec have recorded readings in excess of the maximum acceptable level.

iii) Acid Deposition

- The long term acidification of surface waters in eastern Canada is primarily associated with the deposition of sulphur compounds. However, in some areas already damaged by sulphur deposition, nitrogen deposition may be aggravating acidification. Sulphur compounds are also the major contributor to spring "acid shock". However, deposition of nitrogen compounds is a significant contributor to spring "acid shock" in some areas in eastern Canada.

- No environmental quality targets have been established for nitrogen compound deposition in Canada. The results of international studies suggest that the acidifying effect of nitrogen, measured by excess nitrate leaching, is prevented if total nitrogen deposition (nitrate and ammonia) does not exceed values in the range of 7-20 kilogram per hectare per year for high productivity forests. Lower values have been proposed for low productivity forests; however, the applicability of these targets for Canada has not been demonstrated.

- Observed deposition of nitrogen compounds in all vulnerable areas in eastern Canada appears to be below the level at which acidification damage will occur over the long term (see Figure 2). The limited nitrogen compound deposition data for western Canada suggests the levels are below 2 kilograms per hectare per year.

b) International Obligations

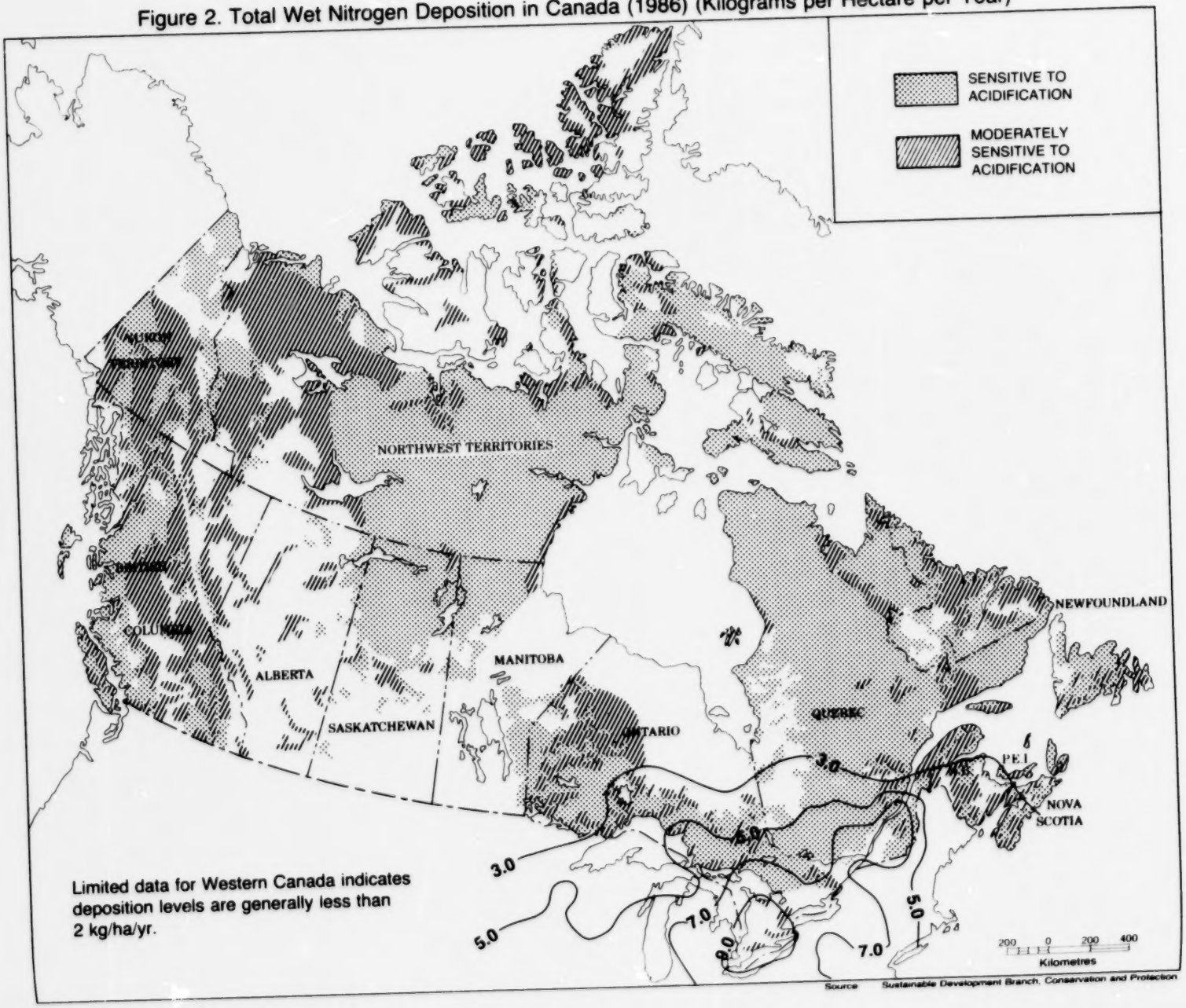
- Under principles of international law and obligation, Canada must ensure that it does not export pollution to the extent of injury to human health or property in a foreign country.

i) Canada/U.S.

- Canada/U.S. discussions on a bilateral accord have been focussed as a first priority on acid rain/sulphur dioxide. However, it is quite possible the eventual conclusion will be an umbrella agreement designed to deal with any existing and future transboundary air pollution problems.

- The U.S. Administration has indicated that NO_x emission reductions will be part of its proposal for acid rain controls. Most of the previously proposed acid rain control legislation in the

Figure 2. Total Wet Nitrogen Deposition in Canada (1986) (Kilograms per Hectare per Year)



U.S. Congress has included measures to reduce NO_x emissions.

- Ozone non-compliance is a major issue in the United States and it is reasonable to expect that any eventual amendments to the U.S. Clean Air Act will include targets and schedules for further control of NO_x and VOC emissions.

ii) ECE NO_x Emission Control Protocol

- Under the aegis of the UN ECE, Canada, the United States and 22 other European member countries have signed an international protocol to control NO_x emissions.

- The basic obligations in the protocol require countries to:

  - ensure that either their total national emissions of NO_x or their transboundary flows do not exceed their 1987 levels by 1994;

  - ensure, within two years of entry-into-force of the protocol, that major new sources of NO_x emissions use pollution control technologies drawn from a slate of best available, economically feasible technologies and that pollution control measures be introduced on major existing sources taking into account the need to, and feasibility of, doing so; and,

  - begin negotiating, within six months of entry-into-force of the protocol, further measures and schedules to control NO_x emissions to the level required to achieve agreed upon environmental quality targets with the first step in the timetable to commence in 1996.

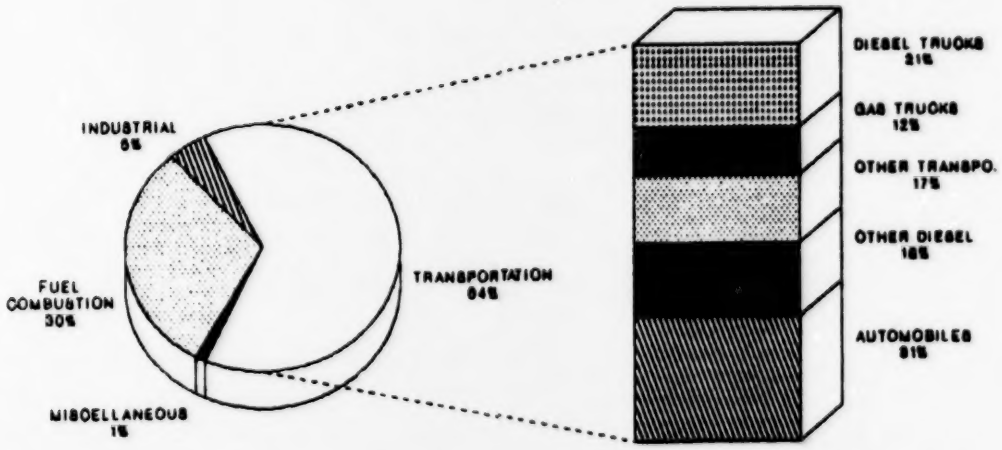
- Two factors should be considered in terms of the post-1996 obligations in the protocol. Canada and the United States must negotiate further measures and schedules to control transboundary NO_x emissions to levels that will prevent damage to the environment. However, in addition to this requirement, there is an emerging international theme that countries should, as a minimum, not increase the amount of pollution released into the atmosphere or their transboundary fluxes. Thus, regardless of the precise legal interpretation of the post-1996 obligations in the protocol, there will likely be considerable pressure within the ECE community for countries not to increase their total NO_x emissions.

c) Current Emissions

i) Nitrogen Oxides

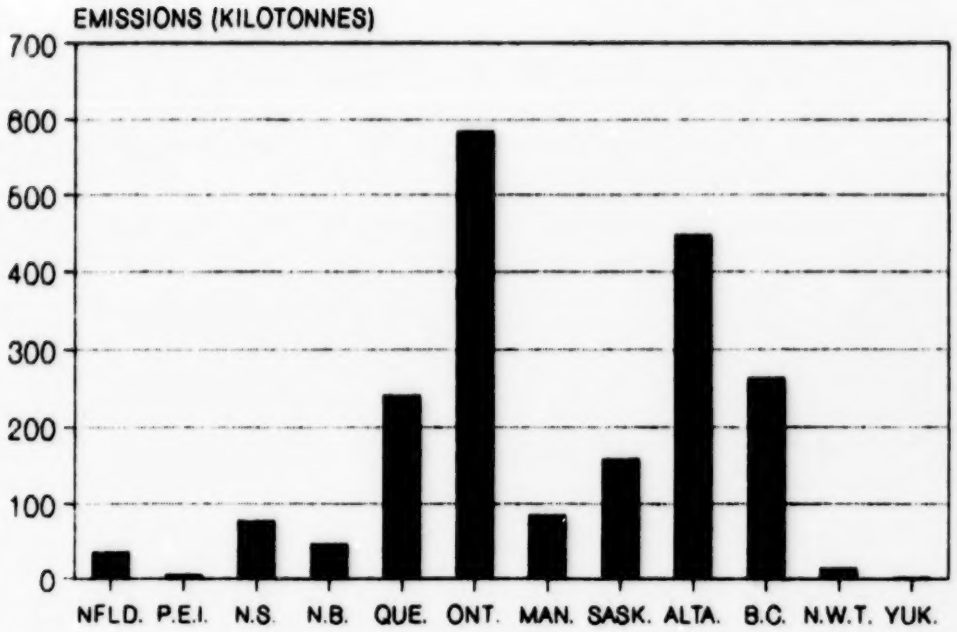
- In 1985, Canadian emissions of NO_x were 1959 kilotonnes. Figure 3 illustrates their distribution by source sector. Transportation (including the off-road use of transportation-type engines) accounts for 64% and stationary fuel combustion 30%. This trend is reflected provincially, with the exception of Alberta, where stationary source emissions predominate due mainly to natural gas sector emissions.

FIGURE 3 SECTORAL DISTRIBUTION OF NO_x CANADIAN EMISSIONS



- The provincial distribution of NO_x emissions is shown in Figure 4.

FIGURE 4 PROVINCIAL DISTRIBUTION OF CANADIAN NO_x EMISSIONS



ii) Volatile Organic Compounds

- Best available 1985 estimates of emissions of VOCs, excluding methane, amount to 1800 kilotonnes. Figure 5 illustrates the national distribution by source sector. As with NO_x, transportation is also the major contributor. Gasoline-powered vehicles account for about 40% of the national total with other transportation sources (including the off-road use of transportation-type engines) contributing an additional 10%. It is anticipated that current VOC emissions will be revised upward in the near future. The current vehicle emission model has recently been found to seriously underestimate evaporative and running losses of VOCs. The other major contributors are industrial processes (14%) and the miscellaneous category which includes fuel marketing operations (6%) and solvent usage (16%).

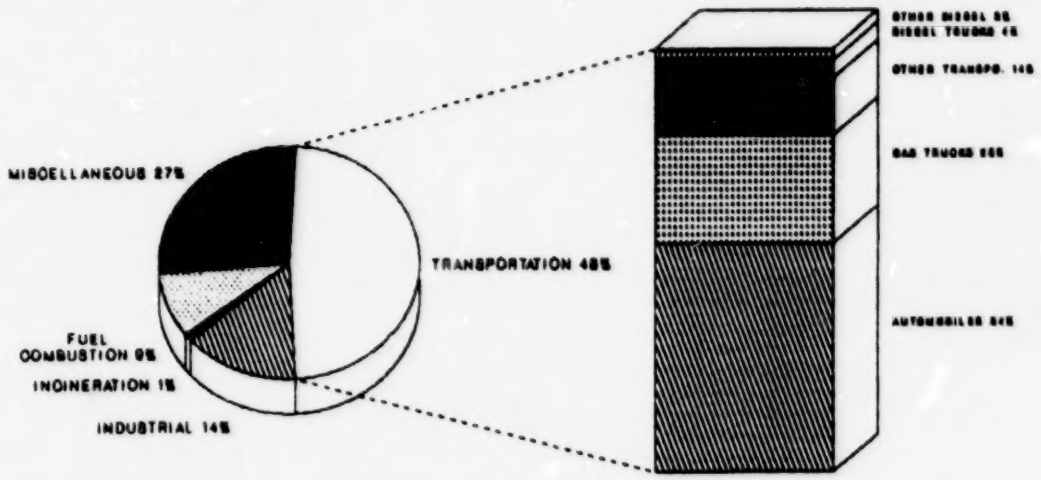
- The importance of VOCs in ozone formation depends on their reactivity. Best estimates of the distribution of Canadian VOC emissions by compound classes are as follows:

- alkanes (moderately reactive) - 62 per cent;
- alkenes (highly reactive) - 16 per cent;
- aromatics (moderately reactive) - 19 per cent;
- aldehydes and ketones (highly reactive) - 3 per cent.

- The distribution is relatively consistent across most emission sectors, with the exception of dry cleaning, where alkanes are about 10 per cent and alkenes about 90 per cent of emissions respectively.

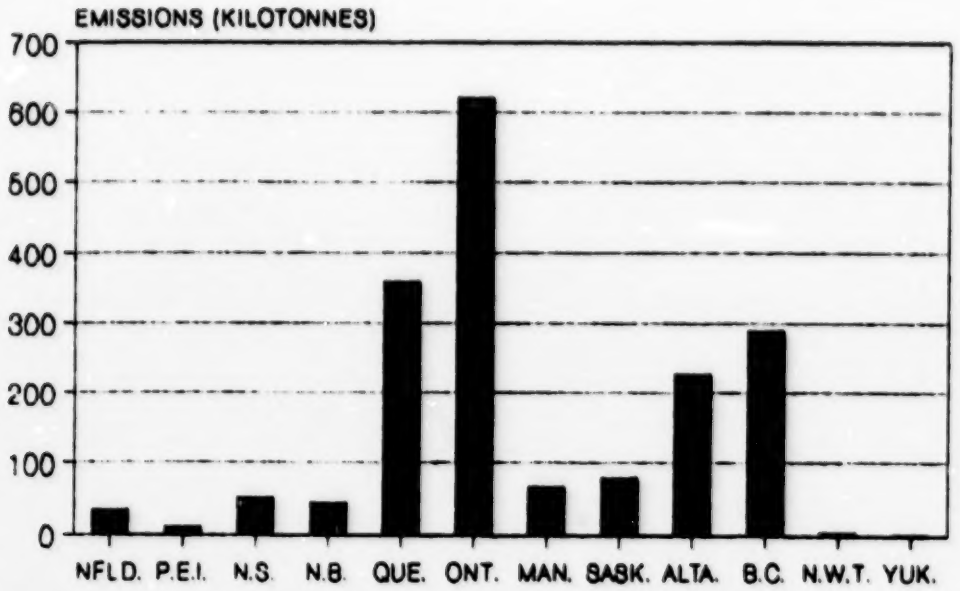
- Concentrations of VOCs in the ambient air in urban areas show a compound class distribution pattern similar to that of emissions.

FIGURE 5 SECTORAL DISTRIBUTION OF CANADIAN VOC EMISSIONS



- The provincial distribution of VOC emissions is shown in Figure 6.

FIGURE 6 PROVINCIAL DISTRIBUTION OF CANADIAN VOC EMISSIONS



d) Projected Emissions

- Projections of future emissions are a forecast against a set of assumptions for such factors as population and Gross National Product growth, energy prices and utilization, number of vehicles and vehicle miles travelled, consumer choices and technology change.

i) Nitrogen Oxides

- Forecasts of NO_x emissions for Canada and the provinces/territories have been generated using 1985 emission estimates as the base year and extending to the year 2005. A summary by province is shown in the Table 4.

TABLE 4 EMISSIONS OF NITROGEN OXIDES
(Thousand Tonnes)

Province	1985	1995	2005	Increase 1985/2005	% of Nat'l Increase
British Columbia	263	268	307	44	9
Alberta	447	513	603	156	33
Saskatchewan	158	167	199	41	9
Manitoba	85	83	96	11	2
Ontario	585	521	685	100	21
Quebec	240	241	265	25	5
New Brunswick	46	65	87	41	9
Nova Scotia	78	84	110	32	7
P.E.I	6	5	6	--	--
Newfoundland	35	34	43	8	2
NWT/Yukon	16	22	25	9	2
TOTAL	1959	2003	2426	467	

- The current national projections show an increase of 467 kilotonnes or 24% in NO_x emissions between 1985 and 2005. Almost all of this increase is forecast to take place between 1995 and 2005. Sectors with significant increases are:

  - thermal power generation-94% (an increase of 234 kilotonnes);

  - off-road diesel engines-40% (an increase of 147 kilotonnes); and,

  - industrial fuel combustion-32% (an increase of 89 kilotonnes).

  These increases are partially offset by a 15% decrease (120 kilotonnes) in emissions from the motor vehicle sector.

- Modifications to the current data set are currently being performed taking into account new information that has or is becoming available

  - new energy demand forecasts prepared by the National Energy Board (NEB).

  - new electric power emission forecasts as generated by Environment Canada.

- new reciprocating compressor engine emission regulations (Alberta Environment).

- new model for forecasting motor vehicle emissions (U.S. EPA MOBILE 4).

- The changes to the forecast will be available for discussion during the first phase of consultations.

- A preliminary review of the new forecasting assumptions indicates the following. A more modest increase in fuel consumption in most mobile and stationary source categories means the increase in NO_x emissions nationally by 2005 is expected to be less than the 467 kilotonnes currently projected. There will also be some changes in the rate and amount by which NO_x emission increases are projected to occur provincially. For instance, the increase in NO_x emissions from power generation is likely to be about half the increase currently projected.

ii) Volatile Organic Compounds

- Forecasts of VOC emissions for Canada and the provinces/territories have been generated using the 1985 national inventory as the base year, and extending to the year 2005. A summary by province is shown in Table 5.

TABLE 5 EMISSIONS OF VOLATILE ORGANIC COMPOUNDS
(Thousand Tonnes)

Province	1985	1995	2005	Increases 1985/2005	% of Nat'l Increase
British Columbia	289	271	293	4	3
Alberta	228	251	272	44	36
Saskatchewan	80	72	74	(6)	(-5)
Manitoba	68	61	63	(5)	(-4)
Ontario	622	605	658	36	30
Quebec	359	365	394	35	29
New Brunswick	46	44	46	--	--
Nova Scotia	54	49	50	(4)	(-3)
P.E.I.	11	11	11	--	--
Newfoundland	36	39	47	11	9
NWT/Yukon	7	8	13	6	5
TOTAL	1800	1776	1921	121	

- The current national projections show an increase of 121 kilotonnes (about 7%) in VOC emissions between 1985 and 2005. All of these increases will occur between 1995 and 2005. Emissions from gasoline-powered motor vehicles are expected to show a reduction of 270 kilotonnes (about a 38% decrease) from the 1985 emission levels. It is not anticipated that this estimate will be revised significantly when evaporative and running losses from gasoline-powered motor vehicles are adequately accounted for. However, emissions from other source sectors are forecast to increase:

  - industrial processes by 84% (an increase of 217 kilotonnes);

  - stationary fuel combustion by 38% (an increase of 61 kilotonnes); and,

  - the miscellaneous category (including use of solvents, gasoline marketing and the application of surface coatings) by 31% (an increase of 153 kilotonnes).

- Modifications to the current data set are currently being performed taking into account new information that has or is becoming available.

  - new energy demand forecasts prepared by the National Energy Board.

  - new model for forecasting motor vehicle emissions (U.S. EPA MOBILE 4).

- The changes to the forecast will be available for discussion during the first phase of consultations.

- A preliminary review of the new NEB energy demand forecasts suggest a more modest rate of increase in fuel consumption in most mobile and stationary source categories than the previous forecast. This is expected to mean that the overall increase from 1985 to 2005 will be somewhat less than 7%. However, total VOC emission estimates for both 1995 and 2005 are expected to be shifted upward by the use of the MOBILE 4 model for automobile emissions.

e) Atmospheric Processes

- Most nitrogen oxides emissions are in the form of nitric oxide (NO). Upon release into the atmosphere, a portion of the NO is quickly converted to nitrogen dioxide (NO_2). This portion increases if VOCs are present. Subsequently, nitrogen dioxide in the presence of high temperatures and sunlight

forms ozone. This chemistry is complex and non-linear. NO_2 can also be oxidized to form nitric acid, an important component of acid deposition.

- Volatile organic compounds can be categorized as non-reactive, moderately reactive and very reactive. Alkenes are the most reactive and produce secondary products, aldehydes and ketones, which are also very reactive in the production of ozone. Alkanes and aromatics, although less reactive, also produce highly reactive aldehydes and ketones as secondary products. Forests are an important natural source of alkenes. The implication is that NO_x controls may be key to preventing ozone formation in rural areas, especially forested regions, where alkenes are in surplus in the ambient air.

f) Atmospheric Models

- A variety of atmospheric models are available to assist decision-makers in developing and evaluating control strategies. These models can provide guidance on the appropriate emissions to control and the amounts to be reduced.

  - Models suitable for application to areas where ozone is largely a local problem (e.g., B.C. lower mainland) are reasonably well developed and tested. Regional scale models for addressing the ozone problems in southern Ontario, southern Quebec and the Maritimes are not as well developed and have not been thoroughly tested. Further work continues on these models.

  - Models are available to address the regional scale deposition of nitrogen compounds and local NO_2 air quality problems.

g) Local Emissions versus Long Range Transport

i) Ozone

- In the B.C. lower mainland, local VOC and NO_x emissions (including sources in the Puget Sound area in Washington) are the cause of ozone episodes. Transported ozone, VOCs and NO_x from the United States are the major cause of ozone episodes in southern Ontario and Quebec.

However, local emissions of NO_x and VOCs are significant contributors. Ozone eposides in the Maritimes are linked primarily to emissions from the northeastern United States, Ontario and Quebec. Local sources aggravate the problems to a limited extent.

- Exceedances of the recommended growing season mean ozone level in most areas in Canda are associated with regional scale emissions of NO_x and VOCs (including natural sources).

ii) Acid Deposition

- Most nitrogen compound deposition in vulnerable areas in Canada is associated with long range transport.

iii) Local NO_2 Air Quality

- Local concentrations of NO_2 are principally associated with local NO_x emission sources although in southwestern Ontario transboundary flows from the United States may be a significant contributor.

h) Canada/U.S. Aspects

- Canada's ability to control ozone and other NO_x and VOC-related pollution problems is limited by the transboundary nature of the problems.

- Ozone concentrations in southern Ontario, southern Quebec and the Maritimes are strongly influenced by long-range transport from the United States. It is estimated that 50-60% of the ozone in southern Ontario comes from the United States. This estimate does not include ozone formed in southern Ontario from precursors originating in the United States.

- In 1980, approximately two-thirds of the nitrogen compounds in the Canadian atmosphere came from U.S. sources and Canada contributed to 3 percent of the nitrogen compounds in the United States.

i) Control Strategies

- The following summarizes the generic nature of the emission management actions that need to be taken in Canada to achieve environmental quality targets. It

must be reiterated that Canadian actions alone cannot achieve environmental quality targets for NO_x and VOC-related pollution problems in Canada. Complementary U.S. actions are essential.

i) Ozone

- The production of ozone is strongly dependent upon the ratio of VOC to NO_x concentrations in the air. Hence, the choice of strategies to control ozone depends upon this ratio (e.g., high ratios require NO_x control, low ratios require VOC control). While the relationship between ozone concentrations and precursor emissions is complex, a few generalities can serve to guide the development of effective controls strategies:

  - controlling VOC emissions will be most effective in reducing ozone episodes in urban areas where local NO_x emissions are high;

  - controlling NO_x emissions will be most effective in reducing ozone episodes downwind of urban areas and in rural areas where natural VOC emissions are high;

  - both NO_x and VOC emission controls will be necessary in areas where both transported ozone and transported VOC emissions are important contributors to ozone episodes; and,

  - regional scale reductions in NO_x and VOC emissions are necessary to meet the recommended growing season mean concentration.

- Actions to further manage NO_x and VOC emissions in Canada will have to be tailored to take account of specific local and regional conditions including current and forecast NO_x and VOC emissions, air chemistry, long range transport of pollutants, Canada/U.S. transboundary flows and "background" ozone levels.

- However, in general, substantial reductions in both NO_x and VOC emissions will be necessary to deal with urban ozone episodes, suburban and rural ozone episodes and growing season mean ozone levels.

ii) Local NO_2 Air Quality

- Local NO_2 air quality problems can be ameliorated by reducing local emissions.

iii) Acid Deposition

- Reducing deposition of nitrogen compounds caused by anthropogenic atmospheric emissions can be accomplished by controlling regional scale NO_x emissions.

Summary of the Nature of the Problems

- About one half of the Canadian population is exposed to ground level ozone concentrations which are known to have health effects. Ozone levels in many agricultural areas in Canada exceed the recommended level to protect crops during the growing season.
- Ground-level ozone is the key NO_x and VOC-related ambient air quality problem in Canada; actions necessary to achieve environmental quality requirements for ozone will result in all other NO_x and VOC-related domestic environmental quality requirements being met with the exception of those that may be established for specific toxic VOCs.
- In the absence of further emission management actions, Canadian emissions of NO_x and VOCs are currently forecast to increase by 24 percent and 7 percent respectively between 1995 and 2005.
- The scientific understanding of the nature, causes and solutions of NO_x and VOC-related environmental quality problems is adequate to proceed with further emission management actions and to know that these actions will produce the intended results.
- Achieving domestic environmental quality requirements for ozone necessitates further management of NO_x and VOC emissions on a regional basis in Canada and reductions in the transboundary flows of these pollutants from the United States.
- Existing and emerging international environmental obligations indicate that, as a minimum, total national emissions and/or the transboundary flows of NO_x and VOCs must not increase above existing levels.

- Thus, in addition to the actions required to achieve domestic environmental quality requirements, agreements and measures must be put in place to manage total national emissions and transboundary flows of NO_x and VOCs.

- The principal sources of current and future NO_x emissions in Canada are motor vehicles, off-road diesels, natural gas production and power plants; the principal sources of current and future VOC emssions in Canada are gasoline-powered motor vehicles, the gasoline fuel cycle from production to vehicle refuelling, refineries and petrochemical plants, application of surface coatings and solvent use.

3. NATURE AND SCOPE OF POSSIBLE CANADIAN ACTIONS

a) Currently Available Emission Control Technologies

- Technologies are available to reduce NO_x and VOC emissions from most of the sources in Canada.

i) Nitrogen Oxides

- Technologies to control NO_x emissions range from improved catalysts and air-fuel mixture control on motor vehicles to optimization of design and operation of on-road and off-road diesel engines, to a variety of combustion and flue gas cleanup technologies for stationary sources. The potential reductions and costs of selective application of these technologies are shown in Table 6.

TABLE 6 ILLUSTRATIVE EFFECTIVENESS AND COST OF SELECTED NO_x EMISSION MANAGEMENT ACTIONS

ACTION	Reduction in 2005 (kt)	Cost per tonne ($)	Annual Cost in 2005 ($ million 1987)
New Gasoline Vehicles			
• improved catalysts, air-fuel mixture control and exhaust gas recirculation	87	570-1150	50-130*
In-Use Vehicles			
• inspection and maintenance programs	26	9800	255*
Off-road Diesels			
• optimization of engine design and operation	75	600-2000	45-150
Diesel Locomotives			
• optimization of engine design and operation	71	1100	78
New Industrial Boilers			
• low-NO_x burners	9	0	0
• selective catalytic reduction	29	4040-6070	117-176
Existing Industrial Boilers			
• low-NO_x burners	36	200-400	7-14
• selective catalytic reduction	115	4310-6440	500-740
Reciprocating Compressor Engines			
• optimization of engine design and operation	63	18-23	290-360
New Power Plants			
• selective catalytic reduction	89	4040-6070	360-540
Existing Power Plants			
• low-NO_x burners	49	200-400	10-20
• selective catalytic reduction	285	4310-6440	1270-1900

* costs for both NO_x and VOC controls

- If currently available technologies were applied consistently across the country, NO_x emissions could be reduced by about 800,000 tonnes per year in 2005 at an annual cost in that year of $2 billion to $3 billion. Selective application of technologies within sectors and/or geographically to achieve a lower emission reduction would substantially reduce the annual cost.

ii) Volatile Organic Compounds

- Technologies to control VOC emissions include:
  - improved catalysts and evaporative systems for gasoline motor vehicles;
  - vehicle emission inspection and maintenance programs to ensure technology performance;
  - reductions in gasoline volatility and vapour balancing at service stations and bulk gasoline terminals; and
  - incineration and/or carbon adsorption filtration of industrial source emission gases.
- The potential emission reductions and costs of the application of these technologies on selected source sectors are shown in Table 7.
- Application of selected currently available technologies consistently across the country would reduce VOC emissions by about 600,000 tonnes per year in 2005 at an annual cost in that year of $600 million to $2 billion. Selective application of technologies to achieve a reduction of less than 600,000 tonnes would substantially reduce the annual cost.

b) Emerging Emission Control Technologies

- There is research underway that could result in more cost effective technologies being available to control NO_x and VOC emissions in the 1995-2005 period.

c) Product Substitution

- In addition to the use of VOC emission control technologies, the reduction and/or elimination of VOC emissions can also be achieved by product substitution.

TABLE 7 ILLUSTRATIVE EFFECTIVENESS AND COSTS OF SELECTED VOC EMISSION REDUCTION ACTIONS

ACTION	Reduction in 2005 (kt)	Cost per tonne ($)	Annual Cost in 2005 ($ million 1987)
New Gasoline Vehicles			
• improved catalyst air-fuel mixture control and exhaust gas recirculation	56	1430-2320	50-130*
• improved vapour control systems on vehicles	28	180-360	5-10
• improved on-board systems to prevent refueling losses	30	0-1500	0-45
In-Use Vehicles			
• inspection and maintenance	97	2360	255*
Reduced Fuel Volatility			
• vehicles	50	3800	190
• marketing	17	2800	48
Gasoline Marketing			
• vapour balancing and recovery during distribution	65	(-300)-560	3-12
• vapour balancing for vehicle refuelling	33	1250	42
Refineries			
• increased use of floating roofs, inspection and maintenance programs vapour recovery during gasoline loading	46	(-350)-15000	6-24
Petrochemical Plants			
• adsorption and incineration	97	25-6200	2-600
Surface Coating			
• adsorption and incineration and product reformulation	67	0-10000	0-670
Dry Cleaning			
• adsorption and incineration	17	0-4000	0-70
Solvent Use			
• adsorption and incineration	39	0-17	0-1
Fuelwood Combustion			
• use of oxidation catalysts and reduction in burning of fuel wood	41	-	-

* costs for both NO_x and VOC controls

- Surface coating products could be reformulated using a higher solids content or substituting water for the solvent base. Clean-up and thinning solvents used in conjunction with surface coatings could also be reformulated using lower vapour pressure solvents and/or water based clean-up formulations.

- Solvent degreasing is usually carried out in packaged degreaser units using chlorinated synthetic solvent or petroleum based solvent. It may be feasible to require that these devices use solvents that are less reactive in ozone formation or that they use lower vapour pressure solvents.

- Many small and large dry cleaners are presently using perchloroethylene as the laundering solvent. This material is a suspected carcinogen. The substitution of a lower vapour pressure solvent would reduce the emissions from these sources.

- A wide variety of aerosol and non-aerosol products such as paints, insecticides, cleaning solutions and automotive and personal care products contain and release VOCs during use and disposal. The major source of VOCs from these products are the solvents in the product formulations and the aerosol propellants. VOC emissions from these products may be successfully reduced by requiring reformulation of the products and the use of non-reactive propellants. Another viable control method would be the substitution of alternative application methods such as pumps, sprays, and squeeze bottles.

- The VOC emissions from solvent-borne adhesives may be controlled by the use of low VOC formulations, water-based adhesives, and hot-melt (solventless) adhesives.

- Methanol and liquid natural gas are being used as substitutes for gasoline in some areas to reduce VOC emissions; although, there is not consensus on their overall effectiveness in ozone control.

d) Transportation Alternatives

- Transportation is the single largest source of NO_x and VOC emissions in Canada. Increased use of mass transit in urban areas could substantially reduce emissions from this sector. In addition, advances have also been made to the point where electric powered vehicles could be considered for use in urban areas.

e) Energy Sector

- Fuel use and electricity demand are the dominant energy related-factors contributing to current and future NO_x emission levels in Canada. Decisions on both the supply and demand sides could play a large role in the plan of action to further manage these emissions.

i) Energy Supply

- Canadians have a wide range of primary energy sources from which to choose. These include: oil, gas, coal, hydroelectricity, uranium, upgraded oil sands, solar, wind, geothermal and tidal energy and biomass energy. However, the supplies and end-use demands differ greatly across the country and no single energy path can simultaneously satisfy all of the needs. The market place will, in large measure, determine the extent to which individual energy sources play a role in Canada's future energy supply mix. Intervention in the allocation process may be appropriate when markets are not sufficiently competitive and when there are social costs, such as environmental objectives, that prices may not reflect or social benefits, such as research and development, which markets may not reward adequately.

ii) Recent Energy Productivity Improvements

- Energy productivity improvements put in place in Canada between 1973 and 1986 are estimated to have avoided some 200,000 tonnes of NO_x emissions and more than 450,000 tonnes of SO_2 emissions in 1986. This represents about 10 per cent and 13 per cent respectively of total national emissions of these pollutants. These improvements also provided substantial economic benefits.

iii) The Future of Energy Productivity Improvements

- Even with these improvements, the best available technology far surpasses the energy efficiency of existing stock in every sector of the economy. The technical and economic potential for retrofit is large. The International Energy Agency conservatively estimates that energy conservation could contribute a further 30 per cent reduction in Canadian energy intensity if market distortions and other barriers are cleared away.

- For instance, measures such as more efficient commercial lighting systems, adjustable speed drives on industrial motors and more efficient electrical appliances have the potential to off-set increases in electricity consumption and even result in negative growth rates. Equally, the energy conversion efficiency of thermal power plants and large industrial boilers is only about 35 per cent. Substantial improvements could be made through the use of advanced combustion technologies.

- In Canada, over half of the fuels and electricity consumed by industry are used by the primary metals, industrial chemicals, and pulp and paper sectors. Even small improvements in energy productivity in these sectors could significantly reduce future NO_x emissions.

- There is also a large potential for improvements in the fuel efficiency of motor vehicles. Since the transportation sector is the largest source of both NO_x and VOC emissions in Canada, fuel efficiency improvements in this sector could play a key role in the further management of these emissions.

- The extent to which potential energy productivity improvements in Canada can be realized will depend, in large measure, on the extent to which real and perceived barriers can be overcome.

    - Energy conservation investments may appear less attractive than other more familiar approaches, including those which do not take full account of externalities and social costs.

    - There is inadequate information available to decision-makers and consumers on the potential for, and benefit of, energy productivity improvements.

    - The institutional mechanisms necessary to develop consensus on, and to promote, potential energy productivity improvements are inadequate.

f) <u>Policy Instruments for Managing Emissions</u>

- Implementation of environmental policy in Canada is largely based on the use of regulations. These regulations are aimed at directly influencing the performance of polluters by limiting emissions or restricting activities in some specific manner. They normally leave the polluter with limited choices in terms of how to comply with the regulation.

- Market forces can also be used to influence decision-making and behaviour in such a way that alternatives are chosen that lead to the environmental situation desired. Market-force instruments include such things as emission charges, raw materials input charges and marketable pollution rights. They tend to allow emitters to respond to a situation in a way that they themselves think most beneficial.

Summary of Nature and Scope of Possible Canadian Actions

- A menu of technologies and other measures are available to further manage current and future emissions of NO_x and VOCs in Canada.
- Canadian actions to further manage NO_x and VOC emissions from stationary sources should focus on:
  - emission reductions at existing power plants with the degree of reduction being a function of such factors as the use and the life expectancy of the unit;
  - application of stringent emission limits on new sources based on best available technology that is economically achievable;
  - emission reductions at refineries and petrochemical plants through the use of best available technology that is economically achievable;
  - emission reductions from the application of surface coatings and use of solvents through the use of best available technology that is economically achievable and/or product substitution or reformulation;
  - implementation of energy productivity improvements; and,
  - development and use of intrinsically clean process technologies and energy production technologies.
- Canadian actions to further manage NO_x and VOC emissions from mobile sources should focus:

- emission reductions in the gasoline fuel cycle from production to vehicle refueling through the use of best available technology that is economically achievable, reducing fuel volatility and altering fuels and fuel composition;
- tightening new vehicle emission standards (tailpipe and evaporative losses) to state-of-the-art levels;
- implementation of inspection and maintenance programs for in-use vehicles to ensure technology performance;
- implementing emission standards for new on-road and off-road diesel engines based on state-of-the-art design and operation; and,
- development and use of intrinsically clean modes of transportation.

- The plan of action to further manage NO_x and VOC emissions in Canada should utilize both regulations and market-force driven initiatives.
- Any Canadian actions to further manage NO_x and VOC emissions should take into account their impact on other related problems such as acid rain, global warming, stratospheric ozone depletion and toxic air pollutants and the actions that are being taken, developed or contemplated to deal with these problems.

4. JURISDICTIONAL AUTHORITIES AND RESPONSIBILITIES FOR NO_x AND VOC EMISSION MANAGEMENT IN CANADA

- Jurisdictional authorities and the geographic extent of application of the illustrative control options outlined in Section 3 of this report are reflected in Table 8.

TABLE 8 ACTIONS AND AUTHORITIES

Source Sector	National/ Federal	Regional/ Provincial	Local/ Municipal
Mobile Sources			
New Gasoline Vehicles	X		
In-Use Vehicles		X	
Off-Road Diesels	X		
Locomotives	X		
Stationary Combustion Sources			
New Industrial Boilers	X	X	
Existing Industrial Boilers	X	X	
New Power Plants	X	X	
Existing Power Plants	X	X	
Reciprocating Compressor Engines		X	
Industrial Processes			
Refineries	X	X	
Petrochemical Plants	X	X	
Miscellaneous			
Reduced Fuel Volatility	X	X	
Gasoline Marketing	X	X	X
Surface Coatings	X	X	
Dry Cleaning	X	X	
Solvent Use	X	X	
Fuelwood Combustion	X	X	

- In addition to the authorities identified, national action could be undertaken on virtually all sources through the development of federal/provincial codes or guidelines agreed upon through CCME.

- The authorities to further manage NO_x and VOC emissions in Canada indicate that the plan of action should be based on the complementary use of federal and provincial authorities.

Summary of Jurisdictional Authorities

The plan of action for further management of NO_x and VOC emissions in Canada should comprise both uniform national actions and regionally tailored actions implemented through the complementary use of federal and provincial authorities

5. TIMEFRAME FOR FURTHER EMISSION MANAGEMENT INITIATIVES

- A number of factors need to be considered in establishing a timeframe for implementing further NO_x and VOC emission management initiatives.
  - In terms of achieving domestic human health and environmental protection requirements, the existing ambient air quality situation in Canada will not improve in the absence of further actions to manage domestic emissions and reductions in transboundary flows.
  - In terms of the ECE NO_x emission control protocol, further emission management measures will be required beginning in 1996.
  - Some new emission management measures could be put in place relatively quickly (2 to 3 years); others may require longer timeframes (5 to 10 years.
- The plan of action for further management of NO_x and VOC emissions in Canada should take a phased approach incorporating all measures necessary to meet domestic environmental quality requirements and international obligation by 1999.

Summary of Timeframe
The specific plan of action for further management of NO_x and VOC emissions in Canada should be a phased program with all necessary mesures in place by 1999

6. ISSUES SURROUNDING THE DEFINITION OF NO_x AND VOC-RELATED PROBLEMS AND THE NATURE AND SCOPE OF POSSIBLE CANADIAN ACTIONS

a) Problem Definition

The issues described in this section are essentially scientific and technical in nature. Reaching concensus on them is important for the development of a detailed plan of action.

i) Environmental Quality Targets

There are a number of issues that must be dealt with in defining Canadian NO_x and VOC-related problems.

- Growing season average concentration for ozone to protect sensitive agricultural crops; while an environmental quality target has yet to be formally established, a recommended level of 64 ug/m^3 has been developed by the Federal/Provincial Air Quality Advisory Committee. The recommended level is based largely on agricultural crops grown in southwestern Ontario. The recommended level is known to be exceeded in many parts of the country although the agricultural crops grown in many areas are not the same as those grown in southwestern Ontario.

  - The issue is that if the recommended growing season mean ozone concentration is used as one of the environmental quality requirements for the plan of action, it will likely be the "driving" parameter for NO_x emission reduction actions in most areas of the country.

- Environmental quality target for nitrogen compound deposition; while one has yet to be recommended for Canada, empirical evidence and current deposition rates suggest that long term acidification due to nitrogen compounds is not occurring in Canada. The ECE has developed a fairly broad range of nitrogen compound deposition targets to protect environments of differing sensitivities. The maximum Canadian deposition rates fall in the middle of this range.

  - The issue is that should an environmental quality target for nitrogen compound deposition in Canada be set at the most stringent level being suggested by the ECE for the most sensitive environments, this could

become one of the driving parameters for actions in eastern Canada.

- Environmental quality targets for VOCs; no environmental quality targets have been established for VOCs as a class of pollutants; in the context of defining the issues at hand, VOCs have been dealt with on the basis of their contribution to ground-level ozone formation. Some actions to control VOCs in this context will reduce emissions of VOCs which are known or suspected of being toxic in their own right.

    - The issue is the extent to which VOC emissions which both contribute to ozone formation and are toxic air pollutants in their own right should be dealt with explicitly in the plan of action for reasons beyond their role in ozone formation.

ii) State of the Canadian Environment

There are a number of issues that must be dealt with in determining the state of the Canadian environment and the extent and severity of NO_x and VOC-related environmental quality problems.

- Ambient air quality data for ozone, NO_2 and VOCs in rural areas; ambient air quality data for these pollutants is available only for selected rural areas.

    - The issue is whether the available information is adequate to define the extent and severity of environmental quality problems in rural areas across the country.

- Exceedances of environmental quality targets; environmental quality targets usually contain a safety factor above the concentration of a pollutant in the air or a deposition rate at which damage to human health or the environment begins to occur.

    - The issue is the number and geographic extent of exceedances of an environmental quality target that should trigger the need to take action.

- "Background" levels of pollutants; background concentrations of ozone in Canada have been increasing to the point where they have become a factor in whether some environmental quality targets (e.g., growing season mean for ozone) can be achieved by reasonable measures to control anthropogenic precursor emissions.

- The issue is the extent to which background levels of pollutants should be taken into account in determining the nature and scope of further emission management measures.

iii) Design of Control Strategies

There are a number of issues that must be dealt with in the context of the design of control strategies.

- Emission inventories; current and future estimates of VOC emissions are "best estimates" at this time and may be refined as methodologies are improved.

  - The issue is whether current "best estimates" of VOC emissions provide an adequate basis for determining the nature and scope of further emission management actions.

- Emission forecasts; projecting future emissions is an uncertain process. The complex and interrelated factors that must be considered include inter alia: population and GNP growth; energy prices and utilization; consumer choices; and, technological change. Thus, future emission levels cannot be predicted with certainty, they can only be forecast against a set of assumptions.

  - The issue is the extent to which a set of emission forecasts provide an adequate basis for the development of control strategies.

- Reactivity of VOCs; theoretically, actions to deal with VOC emissions in the context of ozone formation should be based on their reactivity. However, many of the control technologies for these emissions are not species selective.

  - The issue is the extent to which VOC emission control actions will have to focus on reducing reactive VOC emissions by controlling total VOC emissions such that environmental quality targets are achieved (i.e., total VOC emissions may have to be reduced more than is necessary in order to adequately reduce emissions of reactive VOCs).

- Atmospheric chemistry; the atmospheric chemistry of ozone formation is complex and the rate limiting factors are not the same for all situations or parts of the country.

- The issue is the extent to which solutions can and should be tailored to meet specific geographic situations or whether reasonable generalities can serve to guide the development of effective measures for the plan of action.

- Atmospheric models; a variety of atmospheric models are available to identify source/receptor relationships and to assist in developing and evaluating control strategy options. Some of these models are more well developed and tested than others.

  - The issue is the role that model outputs should play in developing and evaluating control strategies and the relative weight that should be given to these outputs in the decision-making process.

- Emerging emission control technologies; the development and demonstration of more cost effective means for controlling NO_x and VOC emissions can be stimulated by setting deadlines for further emission management. Equally, not all emerging technologies will meet their predicted performance (e.g., efficiency and costs).

  - The issue is how emerging technologies should be factored into the development of further emission management requirements in the plan of action.

b) Nature and Scope of Possible Canadian Actions

The issues described in this section are essentially of a policy/political nature. Consensus must be reached on these issues in order that a detailed plan of action can be developed.

i) Principles to be Used for Allocating Further Emission Management Actions and What Role Each of These Should Play in Determining the Allocation

There are a number of principles that should be considered.

- Achieving domestic environmental quality requirements; for areas where environmental quality requirements are being exceeded or will be exceeded in the future.

  - The issue is the extent to which further emission management measures should be

specifically tailored to achieve the desired environmental quality requirement.

- Maintenance of existing environmental quality; for areas where environmental quality requirements are not being exceeded.

  - The issue is the extent to which further emission management measures should be taken to ensure that there is no degradation in existing environmental quality.

- Cost-effectiveness of alternative actions; for any specific emission management need there will inevitably be alternative ways of achieving it (e.g., controlling different emission types [NO_x vs VOCs, relative reactivity of different VOCs], controlling different sources of emissions and applying different levels of controls to the sources).

  - The issue is the extent to which the most cost-effective alternatives should be the options of choice.

- Equity; actions have already been taken to manage NO_x and VOC emissions in some sectors.

  - The issues are the extent to which previous actions should be taken into account in determining the extent to which these industrial sectors should be candidates for further emission management measures and the extent to which some actions in all provinces and industrial sectors should be included in the detailed plan of action.

- Practical implementation of international obligations; regardless of the precise legal interpretation of international obligations, there will likely be considerable domestic and international pressure for Canada, as a minimum, not to increase total national emissions and transboundary flows of NO_x and VOCs.

  - The issues are, what level of emissions should be allowed in each province, and how should these be determined (e.g., population base, gross provincial product, costs of control alternatives, equity, etc.).

- Use of Canadian technologies/expertise; the current and future availability of Canadian technologies and expertise to further manage NO_x

and VOC emissions is not uniform across all source sectors.

- The issue is the extent to which the availability of "made in Canada" solutions should be used to determine the allocation of further emission management measures.

ii) Relationship of Further NO_x and VOC Emission Management Initiatives to Other Issues

Many of the major emitters of NO_x and VOCs are also involved to a less or greater extent in the acid rain, greenhouse effect, stratospheric ozone depletion and toxic air pollutants issues. This raises three problems. First, to a small degree, actions to further manage NO_x and VOC emissions can increase emissions contributing to other problems (e.g., controls which consume additional electrical energy may arguably increase SO_2 and CO_2 emissions). Second, industries faced with demands to control emissions related to a number of problems may find it most cost-effective to come up with a "package" of controls rather than a series of separate controls (e.g., an advanced combustion technology may produce a better package for SO_2, NO_x and CO_2 emission management than a series of separate controls directed to each pollutant individually). Third, industry will probably be more amenable to being partners in a consultation on a package of actions to deal with all the problems their NO_x and VOC emissions contribute to rather than to a series of separate consultations to deal with their contributions to each of the problems.

- The issue is the "ground-rules" that should be laid down for the development of a plan of action for the further management of NO_x and VOC emissions recognizing the different timeframes and mechanisms either in place or planned for developing actions to deal with the other related issues.

iii) Actions that Could Be Taken Now Versus Waiting Until Consultations are Completed

While Ministers instructed that the detailed plan of action be completed by the summer of 1990, the available information indicates that there are a number of actions that will inevitably be incorporated in the plan. These include: further tightening of new motor vehicle emission standards; implementation of in-use vehicle inspection and maintenance programs; reducing gasoline volatility;

and, stringent controls on major new sources of emissions.

- The issue is whether work should begin now on those actions that will inevitably be part of the plan of action or whether all new initiatives should be delayed until all of the stakeholder consultations have been completed.

iv) U.S. Transboundary Pollution

Transboundary flows of NO_x/VOC/ozone are major contributors to environmental quality problems in eastern Canada. U.S. emission control actions are being developed to deal with U.S. domestic problems associated with these pollutants. Ideally, the detailed plan of action for further management of Canadian NO_x and VOC emissions should be specifically tailored to take account of and to complement the U.S. actions. The timing is such that the two plans are being developed in parallel.

- The issue is whether specific Canadian actions to further manage NO_x and VOC emissions such that Canadian environmental quality targets are achieved should be developed on the basis of some reasonable assumptions of the extent to which U.S. actions will reduce transboundary flows and ultimately how the actions being developed separately in Canada and the United States should be brought together.

v) International Competitiveness

Many Canadian emitters of NO_x and VOCs compete in the U.S. and the international marketplaces. Specific emission control requirements do, and will likely continue to, vary from country to country.

- The issues are how to deal with the actions necessary to achieve Canadian domestic environmental requirements and to honour international obligations where Canadian emitters could be put at a competitive disadvantage and how to deal with any competitive disadvantages that may arise.

vi) Uniform National Actions versus Locally Tailored Actions

There is no question that some of the further emission management actions (e.g., tighter new motor vehicle emission standards) will be implemented uniformly across the country. Equally, some actions such as those to reduce emissions from existing

sources will likely be locally tailored. However, there are some actions (e.g., emission requirements for new stationary sources) which could either be uniform across the country or locally tailored.

- The issue is how to deal with actions that fall into the latter category given the regional nature of NO_x and VOC-related environmental quality problems in Canada.

vii) Policy Instruments

Further emission management needs for NO_x and VOCs can be implemented using traditional "command and control" regulations. Consideration can also be given to implementing some of them through the use of market force instruments.

- The issue is the role that market force instruments could play in the plan of action for further management of NO_x and VOC emissions in Canada.

viii) Role of Management Practices in Emission Management

Management practices such as energy productivity improvements, product substitution and reformulation, mass transit and consumer choice (e.g., environmentally friendly products) can play significant roles in reducing NO_x and VOC emissions. Some of these can be implemented using conventional policy instruments such as regulations. Others must be implemented through market forces.

- The issue is how to determine the magnitude of the roles that market-force-driven management practices can play in controlling emissions.

ix) Timeframe for Implementing the Plan of Action

In terms of domestic needs, environmental quality targets for ozone are currently not being met in many parts of Canada. In terms of current specific international obligations, no new actions must be in place before 1996. Using the Canadian Acid Rain Control Program as a benchmark, the kinds of initiatives likely to be required in the detailed plan of action will likely take about 10 years to fully implement.

- The issue is whether 1999 should be set as the year for full implementation of the measures contained in the plan of action.

7. PHASE I CONSULTATION PLAN

- The phase I consultation plan was prepared for the Federal/Provincial LRTAP Steering Committee by Ray Vles of Pat Delbridge Associates.

a) Objective of Phase I Consultations

- Between May and September 1989, consultation with stakeholders will focus on establishing as much common ground as possible on the following aspects of the NO_x/VOC management plan:
  - the nature of the problems to be addressed.
  - the range of solutions which should be considered in greater detail in phase 2 of the development process (commencing Oct/89).
  - the issues raised by the problems and potential solutions.

b) Issues Raised by Stakeholders

- In developing the consultation plan, stakeholders highlighted a number of concerns that they would like to ensure are addressed during the consultation process.
  - The cost effectiveness of actions, including expected benefit and costs; regionally specific actions; and scientific justification for proposed actions.
  - Principles that will be used for allocating emission management actions.
  - International competitiveness, in terms of whether Canadian industrial sources have to do more than those in other countries.
  - The extent to which the plan will deal with the integration of actions on related problems (SO_2/NO_x/VOC/CO_2 controls).
  - The need to set requirements for a number of years to respect industry's planning horizon.
  - Stakeholders would like a clear statement on governments' commitment to improving air quality.
  - Clarification of the basis for setting and the adequacy of environmental quality targets to show how are they set and who/what they are designed to protect.

- Information on the adequacy of the science so that they have reasonable confidence actions are necessary and will achieve the desired results.

- A concern that any actions taken in a sector should be comprehensive, not one in a series and should not aggravate other problems.

- To the extent possible, any actions taken should be compatible with, and support, other social objectives.

c) Proposed Consultation Process

- Twenty stakeholder groups, three federal government departments and federal and provincial members of the LRTAP Steering Committee were interviewed in the course of preparing the consultation plan.

- The recommended consultation process centres around two-day workshops which would be held at the beginning and end of the consultation period.

  - a technical briefing would be held two to four weeks prior to the initial workshop to brief participants on the technical and scientific aspects of the work.

  - The first workshop would focus on creating common ground on some basic issues and identifying other issues on which further work needs to be done by small task forces or technical committees over the consultation period.

  - the final workshop would bring everyone back together to synthesize the discussions that have taken place and prepare findings.

  - it is recommended that 50-75 people participate in the workshops.

  - it is also recommended that an independent facilitator manage the process.

- Phase one consultations will be completed by mid-September, 1989, which will ensure that the results of this process can be included in the Steering Committee's report to Ministers in October.

APPENDIX A

UPDATE TO APRIL 1989 REPORT

TO CCME

(Pages from the original report that are updated in this appendix are: (i), 15, 18, 19, 20, 24, 26, 27, 28)

July, 1989

SUMMARY HIGHLIGHTS

Nature of the Problems

- About one half of the Canadian population is exposed to ground level ozone concentrations which are known to have health effects. Ozone levels in many agricultural areas in Canada exceed the recommended level to protect crops during the growing season.

- Ground-level ozone is the key NO_x and VOC-related ambient air quality problem in Canada; actions necessary to achieve environmental quality requirements for ozone will result in all other NO_x and VOC-related domestic environmental quality requirements being met with the exception of those that may be established for specific toxic VOCs.

- In the absence of further emission management actions, Canadian emissions of NO_x and VOCs are currently forecast to increase by 18 percent and 7 percent respectively between 1995 and 2005.

- The scientific understanding of the nature, causes and solutions of NO_x and VOC-related environmental quality problems is adequate to proceed with further emission management actions and to know that these actions will produce the intended results.

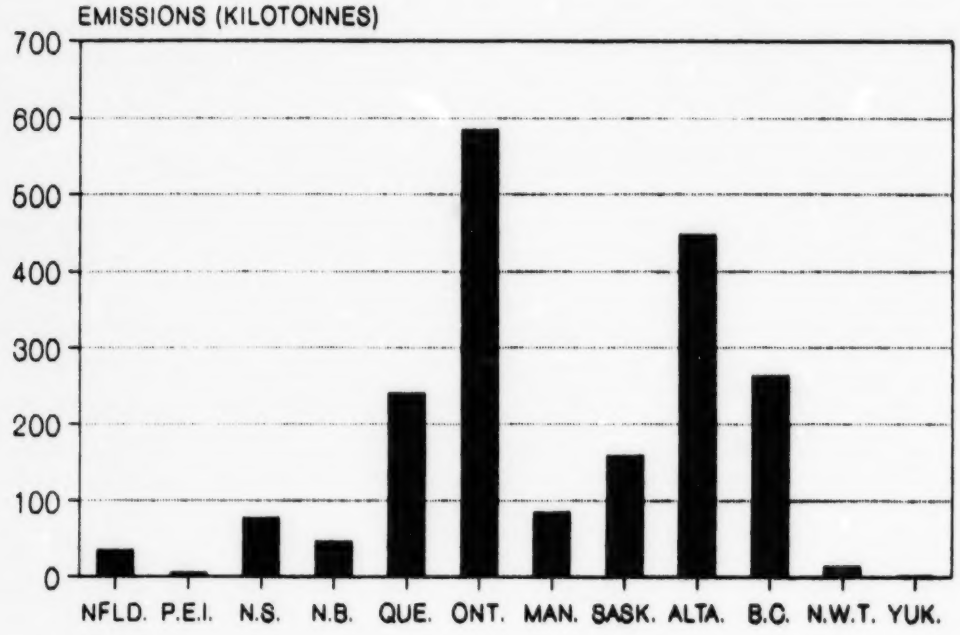
- Achieving domestic environmental quality requirements for ozone necessitates further management of NO_x and VOC emissions on a regional basis in Canada and reductions in the transboundary flows of these pollutants from the United States.

- Existing and emerging international environmental obligations indicate that, as a minimum, total national emissions and/or the transboundary flows of NO_x and VOCs must not increase above existing levels.

- Thus, in addition to the actions required to achieve domestic environmental quality requirements, agreements and measures must be put in place to manage total national emissions and transboundary flows of NO_x and VOCs.

- The principal sources of current and future NO_x emissions in Canada are motor vehicles, off-road diesels, natural gas production and power plants; the principal sources of current and future VOC emissions in Canada are gasoline-powered motor vehicles, the gasoline fuel cycle from production to vehicle refuelling, refineries and petrochemical plants, application of surface coatings and solvent use.

FIGURE 4 PROVINCIAL DISTRIBUTION OF CANADIAN NO_x EMISSIONS



11) Volatile Organic Compounds

- Best available 1985 estimates of emissions of VOCs, excluding methane, amount to 1800 kilotonnes. Figure 5 illustrates the national distribution by source sector. As with NO_x, transportation is also the major contributor. Gasoline-powered vehicles account for about 39% of the national total with other transportation sources (including the off-road use of transportation-type engines) contributing an additional 9%. It is anticipated that current VOC emissions will be revised upward in the near future. The current vehicle emission model has recently been found to seriously underestimate evaporative and running losses of VOCs. The other major contributors are industrial processes (14%) and the miscellaneous category which includes fuel marketing operations (6%) and solvent usage (16%).

- The importance of VOCs in ozone formation depends on their reactivity. Best estimates of the distribution of Canadian VOC emissions by compound classes are as follows:

TABLE 4 EMISSIONS OF NITROGEN OXIDES
(Thousand Tonnes)

Province	1985	1995	2005	Increase 1985/2005	% of Nat'l Increase
British Columbia	263	268	313	50	14
Alberta	447	486	507	60	17
Saskatchewan	158	180	198	40	11
Manitoba	85	89	102	17	5
Ontario	585	575	670	85	24
Quebec	239	233	261	22	6
New Brunswick	48	76	92	44	12
Nova Scotia	78	86	97	19	6
P.E.I	6	6	7	1	<1
Newfoundland	35	36	42	7	2
NWT/Yukon	16	19	25	9	2
TOTAL	1960	2054	2314	354	

- The current national projections show an increase of 354 kilotonnes or 18% in NO_x emissions between 1985 and 2005. Almost all of this increase is forecast to take place between 1995 and 2005. Sectors with significant increases are:

  - heavy-duty diesel trucks - 58% (an increase of 152 kilotonnes);
  - thermal power generation-42% (an increase of 104 kilotonnes);
  - off-road diesel engines-33% (an increase of 123 kilotonnes);

  These increases are partially offset by a 21% decrease (112 kilotonnes) in emissions from the motor vehicle sector (gasoline cars and trucks).

- The current data set has taken into account the following:

  - The most recent energy demand forecasts prepared by the National Energy Board (September, 1988).
  - new electric power emission forecasts as generated by Environment Canada (July 1989).

° the effect of new reciprocating compressor engine emission regulations (Alberta Environment).

° Adjustments have not yet been made to reflect changes in emission estimates that are expected to result from application of the new motor vehicle emission forecasting model (U.S. EPA MOBILE 4 now available to Environment Canada.

ii) Volatile Organic Compounds

° Forecasts of VOC emissions for Canada and the provinces/territories have been generated using the 1985 national inventory as the base year, and extending to the year 2005. A summary by province is shown in Table 5.

TABLE 5 EMISSIONS OF VOLATILE ORGANIC COMPOUNDS
(Thousand Tonnes)

Province	1985	1995	2005	Increases 1985/2005	% of Nat'l Increase
British Columbia	290	274	304	14	11
Alberta	228	222	276	48	36
Saskatchewan	81	71	74	(6)	(-5)
Manitoba	68	59	59	(9)	(-7)
Ontario	621	598	664	43	32
Quebec	362	363	394	32	24
New Brunswick	46	46	48	2	1
Nova Scotia	54	50	51	(3)	(-2)
P.E.I.	11	10	11	--	--
Newfoundland	36	36	48	12	9
NWT/Yukon	7	7	9	2	1
TOTAL	1804	1735	1937	133	

- The current national projections show an increase of 133 kilotonnes (about 7%) in VOC emissions between 1985 and 2005. All of these increases will occur between 1995 and 2005. Emissions from gasoline-powered motor vehicles are expected to show a reduction of 281 kilotonnes (about a 41% decrease) from the 1985 emission levels. Emissions from other source sectors are forecast to increase:

  - industrial processes by 72% (an increase of 187 kilotonnes);

  - stationary fuel combustion by 24% (an increase of 39 kilotonnes); and,

  - the miscellaneous category (including use of solvents, gasoline marketing and the application of surface coatings) by 26% (an increase of 133 kilotonnes).

- The current data set has taken into account new energy demand forecasts prepared by the National Energy Board (September, 1989).

- Adjustments have not yet been made to reflect changes in emission estimates that are expected to result from application of the new motor vehicle emission forecasting model (U.S. EPA MOBILE 4) now available to Environment Canada. It is expected that new emission estimates with MOBILE 4 will be sustantially higher than the current ones the main change being higher estimates for evaporative and running losses.

e) Atmospheric Processes

- Most nitrogen oxides emissions are in the form of nitric oxide (NO). Upon release into the atmosphere, a portion of the NO is quickly converted to nitrogen dioxide (NO_2). This portion increases if VOCs are present. Subsequently, nitrogen dioxide in the presence of high temperatures and sunlight forms ozone. This chemistry is complex and non-linear. NO_2 can also be oxidized to form nitric acid, an important component of acid deposition.

ii) Local NO2 Air Quality

- Local NO_2 air quality problems can be ameliorated by reducing local emissions.

iii) Acid Deposition

- Reducing deposition of nitrogen compounds caused by anthropogenic atmospheric emissions can be accomplished by controlling regional scale NO_x emissions.

Summary of the Nature of the Problems

- About one half of the Canadian population is exposed to ground level ozone concentrations which are known to have health effects. Ozone levels in many agricultural areas in Canada exceed the recommended level to protect crops during the growing season.

- Ground-level ozone is the key NO_x and VOC-related ambient air quality problem in Canada; actions necessary to achieve environmental quality requirements for ozone will result in all other NO_x and VOC-related domestic environmental quality requirements being met with the exception of those that may be established for specific toxic VOCs.

- In the absence of further emission management actions, Canadian emissions of NO_x and VOCs are currently forecast to increase by 18 percent and 7 percent respectively between 1995 and 2005.

- The scientific understanding of the nature, causes and solutions of NO_x and VOC-related environmental quality problems is adequate to proceed with further emission management actions and to know that these actions will produce intended results.

- Achieving domestic environmental quality requirements for ozone necessitates further management of NOx and VOC emissions on a regional emissions on a regional basis in Canada and reductions in the transboundary flows of these pollutants fron the United States.

- Existing and emerging international environmental obligations indicate that, as a minimum, total national emissions and/or the transboundary flows of NO_x and VOCs must not increase above existing levels.

3. NATURE AND SCOPE OF POSSIBLE CANADIAN ACTIONS

a) Currently Available Emission Control Technologies

- Technologies are available to reduce NO_x and VOC emissions from most of the sources in Canada.

1) Nitrogen Oxides

- Technologies to control NO_x emissions range from improved catalysts and air-fuel mixture control on motor vehicles to optimization of design and operation of on-road and off-road diesel engines, to a variety of combustion and flue gas cleanup technologies for stationary sources. The potential reductions and costs of selective application of these technologies are shown in Table 6.

TABLE 6 ILLUSTRATIVE EFFECTIVENESS AND COST OF SELECTED NO_x EMISSION MANAGEMENT ACTIONS

ACTION	Reduction in 2005 (k)	Cost per tonne ($)	Annual Cost in 2005 ($ million 1987)
New Gasoline Vehicles			
* Improved catalysts, air-fuel mixture control and exhaust gas recirculation	96	940	90
In-Use Vehicles			
* Inspection and maintenance programs	26	4900	128
Off-road Diesels			
* optimization of engine design and operation	56	600-2000	34-112
Diesel Locomotives			
* optimization of engine design and operation	88	1100	97
New Industrial Boilers			
* low-NOx burners	7	0	0
* selective catalytic reduction	24	5000-7500	120-180
Existing Industrial Boilers			
* low-NOx burners	38	200-400	8-15
* selective catalytic reduction	90	8000-12000	720-1080
Reciprocating Compresor Engines			
* optimization of engine design and operation	14	3000-4000	42-56
New Power Plants			
* selective catalytic reduction	56	5000-7500	280-420
Existing Power Plants			
* low-NOx burners	39	200-400	8-16
* selective catalytic	153	8000-12000	1240-1860

° If currently available technologies were applied consistently across the country, NO_x emissions could be reduced by about 600,000 tonnes per year in 2005 at an annual cost in that year of $3 billion to $4 billion. Selective application of technologies within sectors and/or geographically to achieve a lower emission reduction would substantially reduce the annual cost.

ii) Volatile Organic Compounds

° Technologies to control VOC emissions include:

- improved catalysts and evaporative systems for gasoline motor vehicles;

- vehicle emission inspection and maintenance programs to ensure technology performance;

- reductions in gasoline volatility and vapour balancing at service stations and bulk gasoline terminals; and

- incineration and/or carbon adsorption filtration of industrial source emission gases.

° The potential emission reductions and costs of the application of these technologies on selected source sectors are shown in Table 7.

° Application of selected currently available technologies consistently across the country would reduce VOC emissions by about 550,000 tonnes per year in 2005 at an annual cost in that year of $300 million to $2 billion. Selective application of technologies to achieve a reduction of less than 550,000 tonnes would substantially reduce the annual cost.

b) Emerging Emission Control Technologies

° There is research underway that could result in more cost effective technologies being available to control NO_x and VOC emissions in the 1995-2005 period.

c) Product Substitution

° In addition to the use of VOC emission control technologies, the reduction and/or elimination of VOC emissions can also be achieved by product substitution.

TABLE 7 ILLUSTRATIVE EFFECTIVENESS AND COSTS OF SELECTED VOC EMISSION REDUCTION ACTIONS

ACTION	Reduction in 2005 (kt)	Cost per tonne ($)	Annual Cost in 2005 ($ million 1987)
New Gasoline Vehicles			
° improved catalyst air-fuel mixture control and exhaust gas recirculation	56	1600	90
° improved vapour control systems on vehicles	28	180-360	5-10
In-Use Vehicles			
° inspection and maintenance	97	1300	128
Reduced Fuel Volatility			
° vehicles	25	2200	55
° marketing	12	2200	26
Gasoline Marketing			
° vapour balancing and recovery during distribution	63	(-350)-575	(-4)-20
° vapour balancing for vehicle refuelling	34	1250-4050	43-140
Refineries			
° increased use of floating roofs, inspection and maintenance programs vapour recovery during gasoline loading	36	(-350)-15000	3-22
Petrochemical Plants			
° adsorption and incineration	97	25-6200	2-600
° floating roofs, inspection and maintenance programs			
Surface Coating			
° adsorption and incineration and product reformulation	67	0-10000	0-670
Dry Cleaning			
° adsorption and incineration	17	0-4000	0-70
Solvent Use			
° adsorption and incineration Product reformulation and substitution	39	0-170	0-7